COMPARATIVE STUDY OF MECHANISATION TECHNOLOGIES FOR FORAGE PLANT HARVESTING

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Abstract

In Romania, the area cultivated with grasslands and meadows represents somewhere around 33.4% of the country's agricultural area. Due to this aspect, Romania has a high zootechnical potential, especially if we take into account the very fragmented relief. The vegetable mass on grasslands and meadows comes from very different groups of plants, these having higher or lower fodder values or even being toxic. Among the main families found in grasslands we can list the Gramineae, Fabaceae and other botanical families with different fodder values.

The purpose of this paper is to compare the two major types of forage harvesters, these can be shear cutter machines or rotary or inertia cutter machines, these being compared from different aspects. The objectives of this work were the comparative analysis of the influence that different harvesting heights have on the production, the comparative study of the behavior of the device in the field, the analysis of the fuel consumption and the time required for harvesting.

From this research it can be seen that both types of devices have both advantages and disadvantages and finally we can say that when choosing the type of harvesting device we must consider several aspects such as the need and the size of the farm.

Keywords: seminatural grassland's, meadows, cutting machines.

INTRODUCTION

In Romania, due to the relief, which is very fragmented and the agricultural lands that are located on slopes greater than 12 % -15% , they cannot be used for the purpose of arable land, they are used either for the establishment of orchards and vineyards where it is mandatory soil terracing, or permanent or temporary grasslands. Due to the fact that the production obtained from natural and semi-natural grasslands cannot be exploited by humans only through animal products obtained in a fresh or processed state, the existence of the livestock sector, which is a basic branch of agriculture, is mandatory.

The surface of Romania's land fund is 23 839 071 ha, the area cultivated with grasslands and meadows represents somewhere around 33.4% of the country's agricultural teritory (*http://statistici.insse.ro*.).

The composition of the vegetation of the permanent meadows includes different species

that differ according to natural, anthropogenic, zoocenotic and economic factors that vary from one area to another and from one year to another, making different changes in the vegetal carpet. Thus, in the vegetation of the meadows there are valuable species, but also less valuable, non-valuable species, species harmful to the vegetation of the meadows, harmful to animal products, harmful or toxic (Rotar et al., 2019, Pacurar and Rotar., 2014). Grasses represent the most important group of plants that exist in the vegetation of meadows, they develop in most ecosystems, in different ecological conditions. They have a high dominance in the vegetal carpet, often being around 30-50%, they can reach 80% - 90% (Pacurar et al., 2014, 2016, Vaida et al., 2016). *Fabaceae* represent a group of plants with a very high fodder value, a valuable meadow is one in which the percentage of *Fabaceae* is approximately 20%-25% (Rotar et al., 2016., Vaida et al., 2021). Species belonging to other families, except for the *Poaceae, Fabaceae, Cyperaceae* and *Juncaceae* families, are also found in the vegetation of the meadows. They participate somewhere between 20 % - 60 % of the vegetal carpet, the higher their value, the more degraded the grassland is, it would be preferable for the number of species from other botanical families to participate in as low a percentage as possible and those to be of species consumed by animals (Pacurar F., 2020, Gaga et al., 2022, Mirela Cirebea et al. 2020).

Time has proven the main role that mechanization has in obtaining high yields and superior quality by shortening the period of preparation of fodder. Research has shown that by preparing hay on the ground, the highest values of losses are achieved. With the help of mechanization, the following benefits have been achieved: first of all, it is the reduction of work effort, the increase of economic efficiency, the decrease of the labor force per surface unit for obtaining fodder, the removal of the effect of depopulation of the hilly and mountainous area.

Forage plant harvesting machines are specialized machines that carry out operations specific to each forage, they can mow them and leave them on the soil surface in a furrow or across the entire working width with the main purpose of shortening the period of drying or harvesting them and loading them into trailer with the purpose of being used either as green mass or used in obtaining silage.

Mowers are specialized machines that perform the operation of cutting and gathering in a furrow of a certain width and height or leaving them on the entire width of the cutting device, thus shortening the drying period (Ranta O., et al. 2000). An important objective is to establish whether annual grazing or

mowing is more effective in preserving the biodiversity of semi-natural grasslands (Malin T. et al. 2016).

Today, mowing along with grazing are the preferred management practices in the remaining semi-natural grasslands. Mowing, by removing aboveground biomass, means a removal of nutrients. But in recent decades the use of mechanical mowing tools has become more common because they are more time and cost efficient. However, cutting tools, i.e. scythes, mowers, are the mowing techniques of choice among conservation practitioners, although mowers, as well as other tear methods, are believed to damage plants and seeds. Tearing plant stems, as opposed to cutting them, is considered detrimental to the species richness and conservation value of semi-natural grasslands. In addition, opinions were expressed that breaking plant stems into small pieces could lead to litter accumulation (Talle M. et al. 2014). Currently there are several types of cutting apparatus, they can be the classic ones, which are also called shear cutting machines, they can be mounted laterally between the two axles of the tractor or behind it with the help of the clamping triangle of the tractor. Shear cutters can be of several types: with fingers, without fingers, with double knife and mixed. On the lawnmower, the blade/blades can increase fuel consumption, it has been observed that if the blades of a lawnmower are properly sharpened, they can produce the same quality of forage as the same quality of cut as a rotary mower (Pircho M . et al. 2019).

MATERIAL AND METHOD

The study was conducted in an experimental field located between the villages of Vârtești and Zalha, in the Zalha commune, Sălaj county, at coordinates latitude 47°10'46.40 "N and longitude 23°30'34.42"E. From a climatic perspective, the average annual temperature ranges between 7.5 ℃ - 9 ℃ and precipitation levels range between 650 mm - 750 mm. The main representative soil types in the area are *Preluvosol, Luvosol, and Eutricambosol.*

The lowest annual average temperature was recorded in January at -2.6 ℃, while conversely, the highest annual average temperature was recorded in August at 21.5 ℃.

From the perspective of precipitation, it is observed that they were distributed very unevenly, means that has generated a period of pronounced deficit during which a very small amount of precipitation fell, and this aspect was reflected in the low yields obtained in the year 2022. The least amount of precipitation occurred in March with 1.78 mm, and similarly, low precipitation was recorded too in

July with 23.11 mm. Following this deficit period, there was a period of excess in September, during which the highest monthly average for the year 2022 was recorded, with 135.38 mm of precipitation.

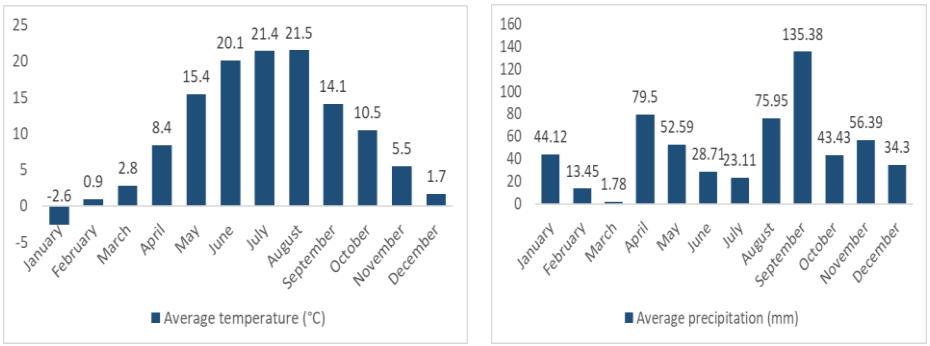

Figure 1 Temperatures and precipitations in the 2022 year

The method employed for the experimental field was the randomized complete block design due to the fragmented nature of the terrain; each experimental variant was arranged randomly to eliminate any influence related to soil or slope. Four replications with an surface of 300 square meters were used, with each replication consisting of four variants. The randomization of each variant within blocks was performed to minimize error (Rusu T., 2020). Each variant differs in terms of the cutting height during harvesting. In variant 1, a mower with a shearing device featuring movable fingers was used, with a working width of 175 cm and a harvesting height of 4 cm - 5 cm. Variant 2 aimed at harvesting plants using a rotating or inertia cutting device (drum mower), where cutting is achieved through impact. The harvesting height is maintained at 4 cm - 5 cm, and the working width is 185 cm. Variant 3 is characterized by a shearing device with movable fingers, with a working width of 175 cm and a harvesting height of 7 cm - 8 cm. Variant 4 is distinguished by a rotating cutting device with drums, with a harvesting height of 7 cm - 8 cm and a working width of 185 cm. The following section will present the experimental field layout using the randomized complete block design method.

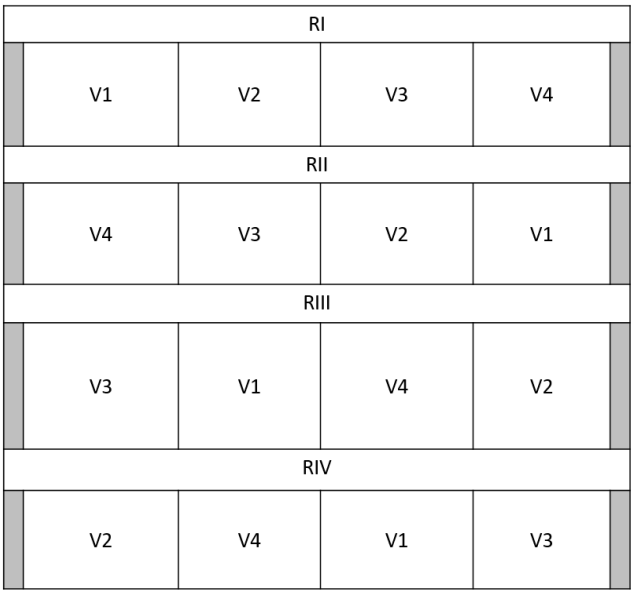

Figure 2 Experimental field layout using the randomized complete block design method with 4 replications

RESULTS AND DISCUSSION

The pastoral value is 2.955, and the experimental field does not exhibit woody vegetation, resulting in a coefficient equal to 1. Additionally, there are no molehills or stones in the field, resulting in a coefficient equal to 1. From the table below, it is evident that the coefficient for the pastoral value is 0.6, denoted by code 06. The pasture qualifies as 6th quality class , falling into a moderate category with a capacity to support a range of 0.81-1.00 UVM / ha. In terms of forage suitability, it is moderately favorable. A detailed analysis of the yields obtained from each variant is presented in Table 1

Table 1

The yields summary table

Number of variant	Yields		Valuable differences Kg / ha	Value
	Kg	%		
V1	543	100	Control	Control
V2	540	99,4	-3	-
V3	507	93,4	-36	-
V4	484	89,1	-59	-

Watching the summary yields table (tabel 1) it indicates that variants number 2, 3 and 4 do not show significant differences compared to the control. From this, it can be inferred that the mower type and harvesting height do not exert a substantial influence on production within wide intervals. However, there is still a possibility of affecting the natural pasture regeneration process.

Table 2

Multiple comparisons using the Duncan test

Number of variant	Yields	2	3	4
		507	540	543
V4	483	24	57	60
V3	507		33	36
V2	540			3
V1	543			

Average error sx= 18,76 kg / variant

Calculation of significance differences: DS 5%=sx*q; DS 5%=18,76*3,20=60,03; DS 5%=18,76*3,34=62,66; DS 5%=18,76*3,42=64,16

The analysis of the soil, stubble and furrow profiles resulting from mowing was carried out on the basis of the 17 control points located at a distance of 10 cm between them. The profile for each variant represents the average of the measurements from the 4 repetitions of each variant.This process involved prior examination of the soil profile, vegetation, an furrow profile.

Following the experiment, it is evident that the highest quantity was obtained from Variant 1, with a harvesting height of 4 cm - 5 cm using a shearing cutting device. The second variant had a slight difference compared to the first, with an average production of 540 kg per variant, equivalent to 18,000 kg per hectare.

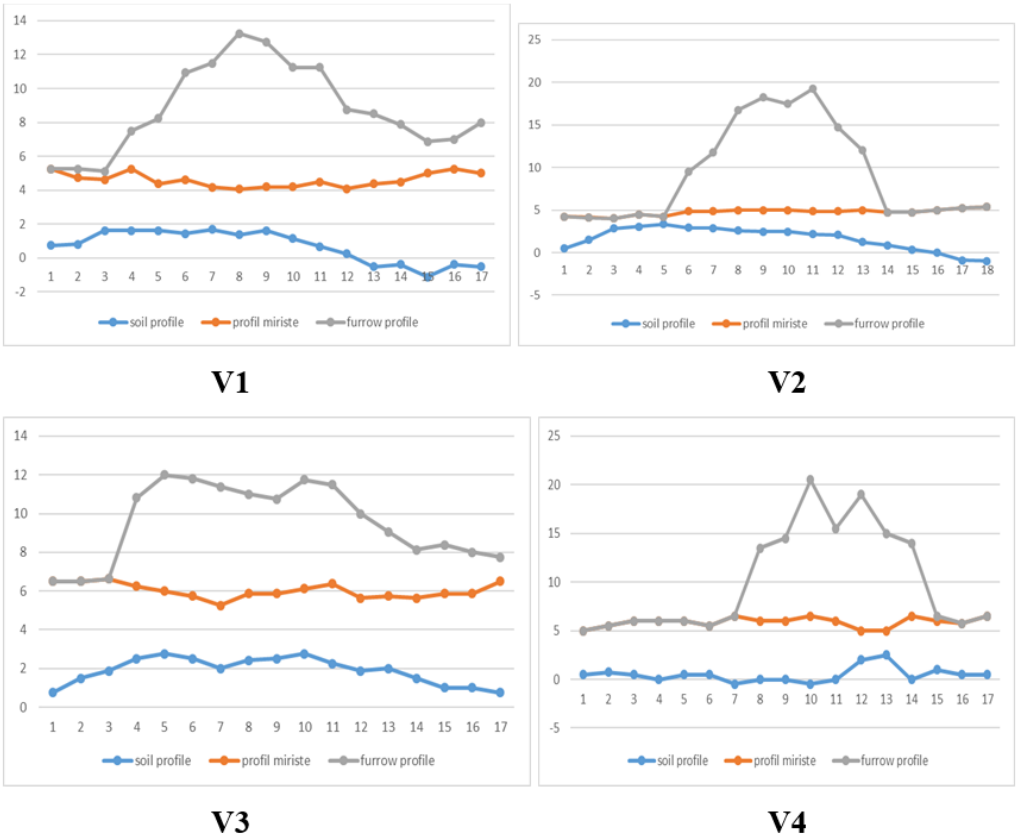

Figure 3 - Analysis of stubble profiles

For Variant 2, the rotary cutter was adjusted to a cutting height of 4 cm - 5 cm. The soil profile was between -1 cm and 3.35 cm and the average value was 1.63 cm. The stubble profile varied in a range close to that of variant 1, this being 4 cm - 5.38 cm and the average value was 4.76 cm. From the point of view of the furrow profile, it was present on a width of 90 cm - 100 cm from the working width of 185 cm. The range of variation is between 4 cm - 19.25 cm, the average being 13.83 cm.

In the case of Variant 3, the soil profile was between 0.75 cm - 2.75 cm and the average value was 1.88 cm.

The profile of the stubble varied in the range of 5.25 cm - 6.62 cm, the average value being 6.02 cm. From the point of view of the furrow profile, it was in the range of 6.5 cm - 12 cm and the average of the profile was 9.53 cm.

The last variant (V4) was represented by a rotary mower with drums, adjusted to a height of 7 cm - 8 cm. From the point of view of the soil profile, it varied in the range of 0.5 cm - 2.5 cm and the average was 0.49 cm. From the point of view of the stubble profile it varied in the range between 5 cm - 6.5 cm

the average value was 5.93 cm From the point of view of the furrow profile it was contained in the range of 5 cm - 20.5 cm and the average value was 13.90 cm

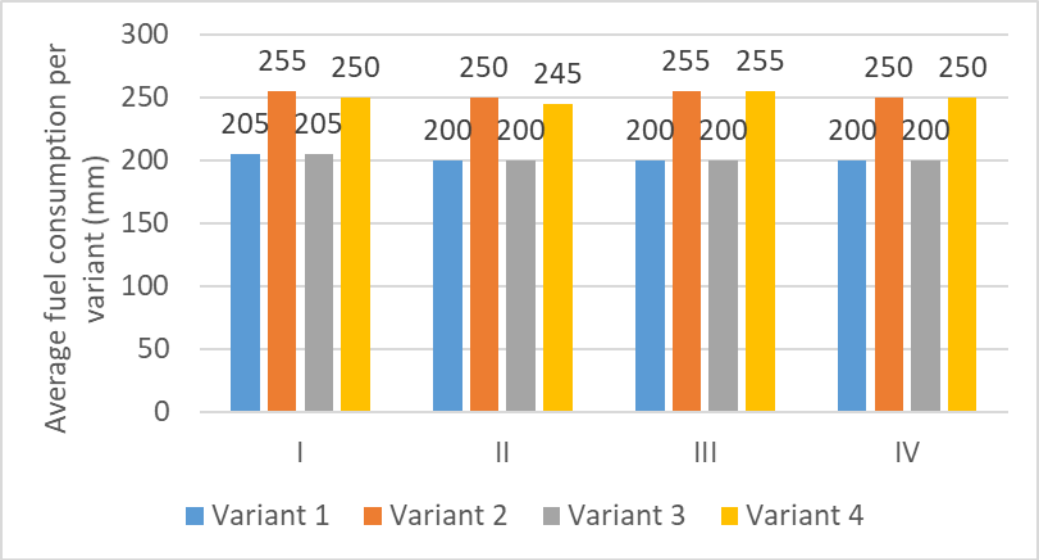

Figure 4 Fuel consumption used for harvesting by variant and repetition

A particularly important aspect is fuel consumption, as it influences production costs and economic efficiency. Due to the rising cost of fuel, it is desirable for fuel consumption to be as low as possible. Based on the data from figure 4, it can be observed that the highest fuel consumption was recorded for the rotary cutting device in Variant 2, followed by Variant 4. In terms of fuel consumption, Variant 1 and Variant 3, both using a shearing cutting device, recorded equal values. In terms of time, it can be noted that variants using a rotary cutting device had a shorter harvesting time compared to those using a shearing cutting device. Therefore, we can deduce that mowers with a rotary cutting device have a higher travel speed regardless of the terrain profile and crop condition. The average harvesting time ranged from 5 and a half minutes to 6 and a half minutes, with a difference of 1 minute.

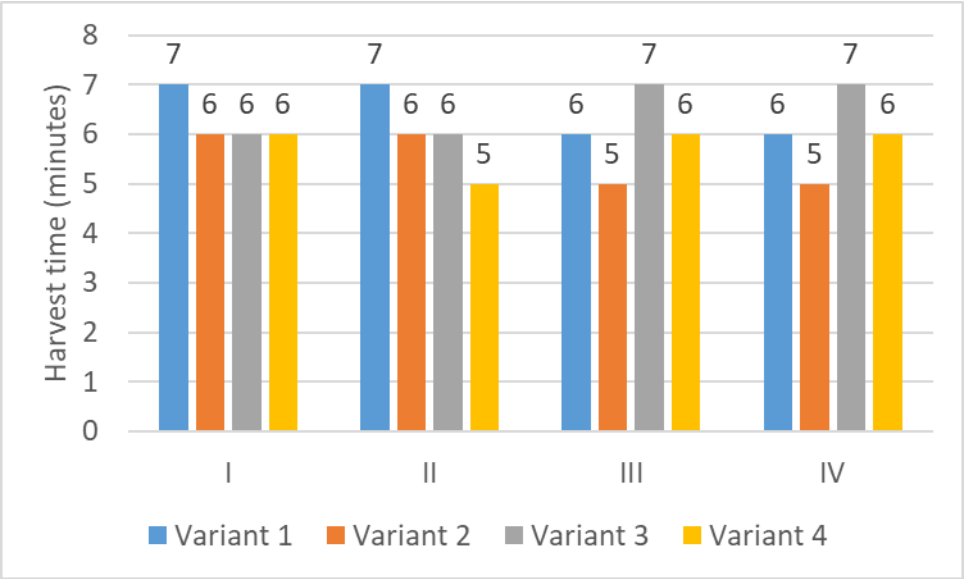

Figure 5 The harvesting time required for each variant and repetition

The following comparison was made between the two types of machines using SWOT analysis for each machine separately.

Tabel 3

SWOT Analysis of shearing cutting device

Strenghts	Weakness
- Reduced acquisition cost. - Low fuel consumption. - Perfect cutting of plants. - Leaves plants uniformly spread across the entire working width. - Low power requirement for operation. - High-quality forage is obtained.	- High maintenance cost. - Slow working speed - Fastly wear of the blade - Difficult blade replacement - Challenges depending on moisture levels. - Difficulties with molehills - Periodic clogging - Requires smooth level terrain - Lower harvesting efficiency
Opportunities	Threats
- Use of non-clogging harvesting machines. - Simultaneous use of multiple harvesting machines. - Use of machines that easily conform the level of terrain.	- The appearance of high-performance mowers that achieve superior qualitative indices.

Tabel 4

SWOT Analysis of rotating cutting device

Strenghts	Weakness
- Lower maitenance cost - High working speed - Higher operational lifespan - Quick replacement of cutting blades - Moisture does not affect harvesting - Molehills are not an issue - No clogging - No need for flat and smooth terrain profile - Reduced harvesting time	- High acquisition cost - Molehills are actually a problem - Higher fuel consumption - Gathering plants in furrows - High power consumption need - Results in an high contamination with dust and soil particles
Opportunities	Threats
- High working speeds - High work productivity	- Contamination of the forage with soil particles due to incorrect adjustment of the cutting device

Regarding the cutting method of plants, shearing cutting devices achieve a much higher quality cut compared to rotating cutting devices. Shearing devices accomplish a straight cut of the plants at the basal level, while rotating cutting devices cause damage to plant tissue, simultaneously leading to contamination with soil particles.

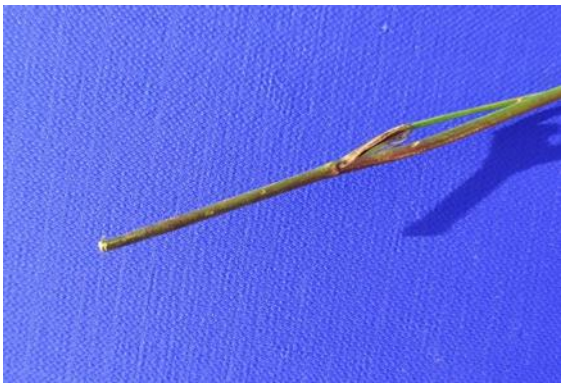

Figure 6
The way of cutting mode of plants using the shearing cutting device

Figure 7
The way of cutting mode of plants using the rotating cutting device

From a cutting standpoint, devices employing shearing or scissoring mechanisms seem to deliver a qualitatively superior cut. However, it is noted that they have lower productivity compared to those operating on inertia.

CONCLUSION

This article aimed primarily at the comparative analysis of the two main types of forage harvesting machines from various perspectives, such as the green mass production in relation to different cutting heights, the comparative analysis of the two cutting methods in terms of plant cutting mode, the comparative analysis of the furrow profile obtained from the two cutting devices, the comparative analysis of the two types of machines in terms of their field behavior, fuel consumption, and the time taken to harvest the variants. Based on the above analyses, it can be concluded that the type of cutting device does not influence green mass production, but it may affect its

digestibility or vegetation cover regeneration. Regarding the behavior in the field, the two mowers behaved differently; the one with shearing cutting device had difficulties with fallen rows or higher working speeds, while the rotary one did not encounter problems. In terms of consumption, the rotary cutting device mower has higher fuel consumption than the one with shearing cutting device.

In conclusion, mowers with a rotary cutting device achieve high work productivity with lower maintenance costs in a shorter period compared to those with a shearing cutting device. However, they have the disadvantage of gathering forage in rows, which complicates the drying process and leads to additional contamination with dust and soil.

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